SUMMARY OF MAJOR CHANGES IN THE THORNYHEAD ASSESSMENT

By

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This year we updated the model introduced in 1997 with available recent data. Further explorations were not pursued since no new data have become available for this species. Results from this year's analyses are very similar to last year's, particularly regarding harvest levels for next year under the $F_{40\%}$ fishing mortality.

The following summarizes the ABC recommendations and status of spawning biomass level for the past few years relative to the current assessment:

Assessment Year	Projection Year	Female spawning biomass	ABC Recommendation
1995	1996	18,535 t	1,560 t
1996	1996	20,768 t	
1996	1997	20,331 t	1,700 t
1997	1996	22,883 t	
1997	1997	22,812 t	
1997	1998	22,778 t	**2,000 t**
1998	1996	23,491 t	
1998	1997	23,473 t	
1998	1998	23,483 t	
1998	1999	23,100 t	**1,990 t**

STATUS OF GULF OF ALASKA THORNYHEADS (*SEBASTOLOBUS SP.*) IN 1998

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Introduction

The shortspine thornyhead (*Sebastolobus alascanus*) inhabits deep waters from 92 to 1,460 m from the Bering Sea to Baja California. Thornyheads are abundant throughout the Gulf of Alaska and are commonly taken by bottom trawls and longline gear. In the past, this species was seldom the target of a directed fishery. Today thornyheads are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan. The population structure of shortspine thornyheads is not well defined. However, as a matter of practical convenience, thornyheads in the Gulf of Alaska have been managed as a single stock since 1980.

According to Alverson et al. (1964), groundfish species commonly associated with thornyheads include: arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), shortraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), and grenadiers (family Macrouridae). Two congeneric thornyhead species, the longspine thornyhead (*Sebastolobus altivelis*) and a species common off of Japan, *S. macrochir*, are infrequently encountered in the Gulf of Alaska.

Catch history

As an element of the deepwater community of demersal fishes, thornyheads have been fished in the northeastern Pacific Ocean since the late l9th century, when commercial trawling by U.S. and Canadian fishermen began. In the mid-l960s Soviet fleets arrived in the eastern Gulf of Alaska (Chitwood 1969), where they were soon joined by vessels from Japan and the Republic of Korea.

Thornyhead catches have been reported in a variety of ways. The earliest records available begin in 1967 as published in French et al. (1977). Active data collection began as part of the U.S. Foreign Fisheries Observer Program in l977, when the thornyhead catch in the Gulf of Alaska was estimated at 1,397 t. From l980 on, the observer program has generated annual estimates of the foreign catch of thornyheads by International North Pacific Fisheries Commission (INPFC) statistical area. Since 1983 the observer program has also estimated the catches of thornyheads in the joint venture fisheries. In l984, thornyheads were identified as a separate entity in the U.S. domestic catch statistics.

Estimated thornyhead catches thornyheads by gear type since 1967 are shown in Table 9.1. Data from 1981 to 1989 are based on reported landings extracted from the Pacific Fishery Information Network (PacFIN) database and the NMFS Observer Program. Prior to this period, estimates are based on the following reports: French et al. (1977), and Wall et al. (1978-81). Catches in more recent years (1990-1994) are based on "blended" estimates provided by the NMFS Regional Office through the Observer

Program. Estimates of discards for these years have been provided as well. The blended and discard estimates are based on a method that makes use of observer data as well as weekly processor reports (WPR). It is interesting to note that for years in which discard information is available, discarding appears to be much more prevalent in the longline fishery than in the trawl fishery. Discards in the domestic fishery prior to 1990 are unknown. We assumed that the reported catches prior to 1990 included both retained and discarded catch.

The catches of thornyheads in the Gulf of Alaska declined markedly in 1984 and 1985 due primarily to restrictions on foreign fisheries imposed by U.S. management policies. The greatest foreign-reported harvest activities for thornyheads in the Gulf of Alaska occurred during the period 1979-83. In 1985, the U.S. catch surpassed the foreign catch for the first time. U.S. catches of thornyheads continued to increase, reaching a peak in 1989 with a total removal of 3,080 t. Catches have since averaged about 1,660 t during the five year period from 1990 to 1994.

By weight, the directed fishery for sablefish harvested the largest amount of thornyheads in 1994 and 1995, followed by rockfish, rex sole and other flatfish (Fig. 9.1). A similar pattern was noted for thornyheads that were not retained, however, thornyhead discards from the sablefish fishery was higher while relatively few discards were incurred from the rex sole fishery. Presumably these differences were due to the timing of these fisheries and differences in abilities to avoid incidental harvests. The distribution of thornyhead catches range broadly throughout the Gulf of Alaska and is consistent within recent years for the different gear types (Figs. 9.2 and 9.3).

Table 9.1. Estimated retained catch and discard levels by gear type. Prior to 1990 retained catch was assumed to equal retained and discard catch combined.

	Trawl			Hook and Line			All Gears Combined		
Year	Retained	Discarded	Total	Retained	Discarded	Total	Retained	Discarded	Total
67	7	-	7	0	-	0	7	-	7
68	56	-	56	6	-	6	62	-	62
69	94	-	94	3	-	3	97	-	97
70	48	-	48	6	-	6	53	-	53
71	230	-	230	11	-	11	241	-	241
72	202	-	202	14	-	14	216	-	216
73	1,550	-	1,550	15	-	15	1,565	-	1,565
74	1,529	-	1,529	8	-	8	1,537	-	1,537
75	1,215	-	1,215	15	-	15	1,229	-	1,229
76	1,189	-	1,189	124	-	124	1,313	-	1,313
77	1,163	-	1,163	234	-	234	1,397	-	1,397
78	442	-	442	344	-	344	786	-	786
79	645	-	645	454	-	454	1,098	-	1,098
80	1,158	-	1,158	327	-	327	1,485	-	1,485
81	1,139	-	1,139	201	-	201	1,340	-	1,340
82	669	-	669	118	-	118	787	-	787
83	620	-	620	109	-	109	729	-	729
84	177	-	177	31	-	31	208	-	208
85	70	-	70	12	-	12	82	-	82
86	607	-	607	107	-	107	714	-	714
87	1,877	-	1,877	93	-	93	1,970	-	1,970
88	2,181	-	2,181	327	-	327	2,508	-	2,508
89	2,616	-	2,616	463	-	463	3,079	-	3,079
90	1,233	38	1,271	284	20	304	1,518	57	1,575
91	1,210	72	1,282	234	497	731	1,444	569	2,013
92	1,042	114	1,156	534	330	864	1,576	444	2,020
93	489	173	663	401	305	706	890	479	1,369
94	493	200	693	309	296	605	802	496	1,298
95	635	143	778	478	107	585	1,413	621	2,034
96	578	141	719	475	116	591	1,297	616	1,913
97	567	224	791	398	61	458	965	284	1,249
98*			1,081			919	1,081	919	2,000

Source: 1967-1980 based on estimates extracted from NMFS observer reports (e.g., Wall et al. l978)
1981-1989 based on PACFIN and NMFS observer data,
1990-1997 based on blended NMFS observer data and weekly processor reports.

* 1998 Projection to TAC (2,000 t) based on NMFS Regional Office report, as of Oct. 22, 1998.

Notes: Catches by gear type from 1981-1986 were estimated by apportioning 85% and 15% of the total all gear catch to the trawl and longline gears respectively.

Resource Surveys

Longline surveys

Longline surveys have been conducted jointly by the United States and Japan in the Gulf of Alaska each year since 1979 to ascertain the abundance level and length composition of important groundfish species in the depths from 101 to 1,000 m. Since 1987 a U.S. longline survey has also been conducted using similar methodology to the cooperative survey. For each species, the catch rate, the area, and the size composition of samples from each depth stratum were used to determine the relative population number (RPN) and weight (RPW) for the depth stratum. The RPNs and RPWs for the various depth strata (201-1,000 m for thornyheads) were summed to obtain GOA totals (Table 9.5).

Table 9.5. Relative population number (RPN) and weight (RPW) from the longline survey. Note that the domestic RPN data from 1990-1997 (second column, lower section) were used to tune the model.

Cooperative survey

Year	RPN	RPW
1979	9,875	5,696
1980	11,823	6,726
1981	12,723	6,793
1982	6,840	4,254
1983	6,893	4,148
1984	5,291	3,115
1985	7,532	4,362
1986	5,411	3,401
1987	5,071	3,294
1988	4,327	
1989	2,449	
1990	2,893	
1991	2,509	

Domestic survey

Year	RPN (97)	RPN (old)	RPW
1988		20,442	11,139
1989		36,262	18,974
1990	43,479	31,879	17,143
1991	56,615	42,007	19,900
1992	73,233	58,587	29,072
1993	66,532	47,320	24,665
1994	49,126	38,844	21,163
1995	58,842		
1996	66,511		
1997	63,009		

Sources: Sasaki and Teshima (1988); Sigler and Zenger (1994); Mike Sigler Unpublished data.

As discussed in previous assessments, longline survey data since 1988 are not strictly comparable for estimates of thornyheads due to differences in vessel operations. Also, the use of the longline survey in general may be questionable because of a possible interaction with sablefish abundance. For example, Sigler and Zenger (1994) found that thornyheads increased in areas where sablefish abundance decreased. They suggested that the increased availability of baited hooks as a result of a decline in sablefish abundance may have been responsible for the increase in thornyheads in the domestic longline survey between 1988 and 1989. Preliminary analysis using a general linear/additive model framework has shown the catch of other species significantly affects catch rates of thornyheads in the longline survey.

For consistency, we chose to include the RPN from the domestic survey in the model. Further research is needed on the effect of hook competition between slow, low metabolism species such as shortspine thornyheads and faster, more aggressive feeding sablefish. Since the abundance of sablefish has fluctuated considerably in the past few decades, we felt that including the data from the cooperative survey was inappropriate. For the period of the recent domestic survey the abundance of sablefish has fluctuated much less during the period for the cooperative survey. The coefficient of variation for the domestic survey index was assumed to be 20%. Size compositions from this survey were used and are presented in the section discussing model fit.

Trawl surveys

The most recent NMFS trawl survey for the Gulf of Alaska was conducted during the summer of 1996. This survey employed standard NMFS Poly-Nor'eastern bottom trawl gear and provide biomass estimates using an "area-swept" methodology described in Wakabayashi et al. (1985). As presented in last year's assessment, the 1984 and 1987 surveys extended into deeper water (>500 m) and covered the range of primary habitat for the shortspine thornyhead stock. Surveys during the 1990s have not extended to the deeper zones where concentrations of larger thornyheads are known to exist. We believe that this causes the biomass estimates to appear disjointed over time (Fig. 9.4). To account for these differences between surveys in the 1980s with recent surveys, we assume that the 1984 and 1987 surveyed the entire adult population while the 1990, 1993, and 1996 estimates surveyed a younger (smaller sized) portion of the stock. This was achieved by a fixed catchability coefficient equal to 1.0 for the surveys in the 1980s and separate, freely-estimated value for the 1990s. We feel that a significant portion of the biomass of shortspine thornyheads exists beyond depths of 500 m, as illustrated by analysis of longline survey catch-per-unit-effort data (Ianelli and Ito 1994). The ability of our assessment to reflect that actual abundance of shortspine thornyheads is hampered by the lack of reliable data in these deeper habitat areas. The spatial distribution of relative thornyhead catch rates observed in the triennial surveys from 1987-1996 indicates higher densities in the western region of the GOA in 1996 (Fig. 9.5).

Analytic approach

Last year a sized based, age-structured model was developed and applied to the thornyhead resource in the Gulf of Alaska. In this assessment, the original model was re-written in C++ computer language in order to take advantage of analytical software designed for building large, complex models.

The conceptual model is similar to that commonly implemented in the stock synthesis program (Methot 1990). Catch data were from 1967 to 1997 with the last six years adjusted to include discards. Prior to this time we assumed harvests of the resource was negligible. Model parameters are estimated by maximizing the log likelihood (L) of the predicted observations given the data. Data are classified into different components. For example, size compositions from a survey and from a fishery represent different components. The total L is a sum of the likelihoods for each component. The total L may also include a component for a stock-recruitment relationship. The likelihood components may be weighted by an emphasis factor. For shortspine thornyheads in the GOA, the model was aggregated to have two fisheries and included the NMFS triennial trawl surveys and the NMFS domestic longline survey. Table 9.2 summarizes the likelihood components used in this assessment. Table 9.3 presents the key equations used for the shortspine thornyheads model in the Gulf of Alaska and a description of key variables is given in Table 9.4.

Table 9.2. Data types used in the model for shortspine thornyheads in the GOA.

Data Component	**Years of data**
Trawl survey size composition and biomass estimates	1984, 87, 90, 93, 96
Longline survey relative abundance and size composition	1990-1997
Trawl fishery size composition data	1977, 1982-84,1990-96
Longline fishery size composition data	1977-81, 1991-95
Trawl fishery harvests	1967-1998
Longline fishery harvests	1967-1998

Table 9.3. Model equations describing population dynamics.

Equations	**Description**
$N_{t,1} = R_t = R_0 e^{\tau_t}$, $\tau_t \sim \mathrm{N}\left(0, \sigma_R^2\right)$	Recruitment
$C_{i,t,a} = \frac{F_{i,t,a}}{Z_{t,a}}\left(1-e^{-Z_{t,a}}\right)N_{t,a}$ $1 \le t \le T$ $1 \le a \le A$	Catch gear type *i*, year *t*, age class *a*
$N_{t+1,a+1} = N_{t,a}e^{-Z_{t,a}}$ $1 < t \le T$ $1 \le a < A$	Numbers
$S_t = \sum_{a=5}^{54+} w_{t,a}\phi_a N_{t,a}$	Spawnings
$N_{t+1,A} = N_{t,A-1}e^{-Z_{t,A-1}} + N_{t,A}e^{-Z_{t,A}}$ $1 \le t \le T$	Numbers in "plus" group"
$Z_{t,a} = \sum_i F_{i,t,a} + M$	Total Mortality
$F_{i,t,a} = s_{i,a}\mu_i^F \exp\left(\varepsilon_{i,t}^F\right)$ $\varepsilon_{i,t}^F \sim N\left(0, \sigma_F^2\right)$	Components of fishing mortality
$s_{i,a} = \exp\left(\eta_{i,a}\right)$ $\eta_{i,a} \sim N\left(0, \sigma_{s_{i,a}}^2\right)$	Age-effect of fishing
$C_{t\cdot} = \sum_{a=1}^{A} C_{t,a}$	Total catch
$p_{t,a} = C_{t,a} / C_{t\cdot}$	Proportion at age in catch
$Y_t = \sum_{a=1}^{A} w_{t,a}C_{t,a}$	Yield
X	Transition matrix dimensioned by 50 ages by 25 length bins, parameterized by growth relationship shown in Figure 6.

Table 9.4. List of variables and their definitions used in this model

Variable	**Definition**
R_t	age 1 recruitment in year *t*
R_0	geometric mean value of age 1 recruitment, 1967-1997
$R_0^{'}$	geometric mean value of age 1 recruitment prior to 1967 (establishes initial age composition)
τ_t	recruitment deviation in year *t*
T	number of years of fishing (i.e., t=1 corresponds to 1967, and t=T corresponds to 1997)
A	number of age classes in the population model (A=50 ranging from a=1 that corresponds to age 5 and a=50 corresponds to fish age 54 and older,
$N_{t,a}$	number of fish age *a* in year *t*,
$C_{t,a}$	catch number of age group *a* in year *t*,
$P_{t,a}$	proportion of the total catch in year *t*, that is in age group *a*,
$C_{t\cdot}$	total catch in year *t*,
$W_{t,a}$	mean body weight (kg) of fish in age group *a* in year *t*,
ϕ_a	proportion mature at age *a*
$Y_{t\cdot}$	total yield weight in year *t*,
$F_{i,t,a}$	instantantaneous fishing mortality for gear type *i*, age group *a*, in year *t*,
M	instantantaneous natural mortality (assumed constant for all ages and years,
$Z_{t,a}$	instantantaneous total mortality for age group *a*, in year *t*,
$S_{i,a}$	age-effect of fishing for age group *a* in gear type *i*, normalized to average 1.0 over ages a=1 to A,
μ_i^F	median year-effect of fishing mortality,
$\varepsilon_{f,t}$	the residual year-effect of fishing mortality (note that effective effort fluctuates in fidelity to the total catch each year).

Parameters estimated independently

Miller (1985) estimated thornyhead natural mortality by the Ricker (1975) procedure to be 0.07. The oldest thornyhead she found was 62 years old. On the U.S. continental west coast, at least one large individual was estimated to have a maximum age of about 150 years old (Jacobson 1990). However, recent radiometric analyses suggest that the maximum age is between 50-100 years (pers. comm., John Butler, SWFC, La Jolla CA). Miller (1985) estimated size-at-age for shortspine thornyheads in the GOA using conventional methods and found the maximum age to be about 60 years old. In past assessments, we attempted to estimate growth within a size-based model using some assumptions from Miller (1985). Here we extend previous assumptions by specifying that a 5-year old shortspine thornyhead has a mean size of 15 cm and a 54-year old fish has a mean length of 51 cm. The von-Bertalanfy growth parameter used to "bridge" these mean lengths, k, was assumed to be 0.022 based on estimates from past assessments. We selected coefficients of variation in length at age to be 9% at age 5 and 8% at age 54 (based on experience with variability in length-at-age with other rockfish; e.g., Pacific ocean perch). These values were used to create the transition matrix which the model used to convert between modeled numbers-at-age to observed proportions at size.

Miller (1985) estimated the length-weight relationship from 232 samples collected in the eastern Gulf of Alaska as follows:

$$\text{weight (kg)} = a(\text{fork-length(cm)})^{b}$$

$$a = 1.3627\text{x}10^{-6}, \quad b = 3.3904$$

As in the previous assessment, we chose the size-at-maturity schedule estimated in Ianelli and Ito (1995) for shortspine thornyheads off of the coast of Oregon. In this ogive, female shortspine thornyheads appear to be 50% mature at about 22 cm or about 11 years old (Fig. 6).

Results/Model evaluation

As presented in last year's assessment, we evaluate uncertainties in the estimate of natural mortality (M) by selecting a prior distribution rather than assuming a fixed value. Initial model runs using a moderately diffuse (uninformative) prior distribution about M indicated that the best fit was attained with a relatively high value of M (given constraints placed on declining selectivity with age). Therefore, we selected a relatively informative prior on M with an expected value of 0.05 and a coefficient of variation equal to 10% (Fig. 7). This resulted in an estimate similar to the fixed value assumed last year (0.07) but still allowed for some accounting of uncertainty in this parameter. As in the past, we selected this configuration in part with the knowledge that it would result in more conservative estimates of ABC's. The fits to the observed size composition data for these results were reasonable (Fig. 9.8).

The fit to the abundance indices was not particularly good (Fig. 9.9). The trawl survey abundance index was within the observed confidence bounds (see Fig. 9.4). However, the model did not fit the increasing trend apparent from either survey. This indicates an inconsistency between the biological aspects of the model specified and observed trends. Given the extremely slow and relatively continuous growth of thornyheads—and the low natural mortality rate that we assume—the level of increase must be attributed to somewhat stronger recruitment in recent years. The problem remains that the observations do not provide information to suggest such strong year-classes have occurred. This is due, in part, to the fact that the distribution of thornyheads is widespread and relatively homogenous (i.e., they do not form highly aggregated schools) and also because the sample size on length frequency from the fisheries is low. Also, the ability to obtain a reasonable progression of length modes may be inherently problematic given the slow and perhaps erratic growth of these fish. A sensitivity analyses on the emphasis placed on fitting the longline survey abundance index shows that the overall model fit significantly degrades with increasing longline survey index emphasis (Ianelli and Ito, 1995). Since the trend of stock increase in either the longline or trawl surveys is over a short time period (less than 10 years) relative to the apparent longevity of this species, we feel that it is not overly conservative to fail in matching an increasing trend. Selectivity estimates for the surveys and fisheries are shown in Fig. 9.10.

Abundance and exploitation trends

Results from the modeling shows that the abundance of shortspine thornyheads has remained relatively stable since 1970 (Fig. 9.11). Fishing mortality rates peaked at about 0.04 in 1989 while for recent years, the rate has remained around 0.02 (Fig. 9.12). The estimates of biomass and recruitment over time are given in Table 9.6.

Table 9.6. Estimates of beginning of year 5+ biomass, female spawning biomass, and recruitment for shortspine thornyheads in the Gulf of Alaska.

Year	Total age 5+ Biomass	Female Spawning Biomass	Age 5 Recruitment
1967	57,972	25,477	44,150
1968	58,814	25,886	42,304
1969	59,640	26,312	44,611
1970	60,560	26,754	53,565
1971	61,868	27,249	77,043
1972	62,995	27,678	71,561
1973	63,977	28,131	53,176
1974	63,508	27,950	48,288
1975	63,079	27,791	50,011
1976	62,906	27,785	45,717
1977	62,483	27,726	34,485
1978	61,895	27,610	31,621
1979	61,885	27,778	30,739
1980	61,501	27,775	30,178
1981	60,638	27,550	28,456
1982	59,834	27,344	26,267
1983	59,579	27,357	29,417
1984	59,409	27,350	35,236
1985	59,964	27,560	51,613
1986	60,694	27,808	53,864
1987	60,789	27,723	54,192
1988	59,981	27,070	75,092
1989	58,720	26,285	58,420
1990	57,128	25,319	63,981
1991	56,354	24,884	40,710
1992	55,845	24,304	92,353
1993	54,842	23,786	43,690
1994	54,511	23,624	41,973
1995	54,276	23,549	42,232
1996	53,847	23,491	31,395
1997	53,503	23,473	35,135
1998	53,216	23,483	35,569

Recruitment

Results from the present study confirm Miller's (1985) suggestion that year class success is variable for shortspine thornyheads in the GOA. Several strong year-classes were apparent but the ability to resolve the precise recruitment year was poor. This is due to the fact that the thornyheads appear to grow very slowly and have a variable size-at-age relationship that can mask signals of strong year-classes. A plot of the estimated stock and recruitment is very uninformative because of the lack of contrast in spawning biomass levels over the period for which estimates were available (Fig. 9.13).

Projected catch and abundance

Thornyhead exploitable biomass projected to the year 2003, assuming average recruitment of 5 year olds, shows a slow decline when fished at the $F_{40\%}$ rate (Fig. 9.14). Similarly, yields show a slow short-term decline at the $F_{40\%}$ rate (Fig. 9.15).

Maximum sustainable yield (MSY) calculations require assumptions about the stock recruitment relationship, which for shortspine thornyheads may be impractical as many functional forms can fit the data equally well. As presented above, the $F_{40\%}$ harvest strategy was selected in the absence of information on the stock-recruitment productivity relationship required for calculating MSY levels.

Reference fishing mortality rates and yields

The quantities for making harvest recommendations differ considerably from those used in previous assessments of the GOA shortspine thornyhead resource. This assessment uses a time-series of data from several different sources and attempts to provide a more comprehensive view of the current status of the fishery as well as its history. The values for average fishing mortality and yields are given in Table 9.7 with the historical estimates given in Table 9.8.

Since management of thornyheads is not specific to different types of fishing gear, (i.e., there are no direct allocations of the TAC) the fraction of the TAC harvest by trawl versus longline gear is unpredictable. For our recommendations, we assume that the relative proportions of the SPR (spawning-biomass per recruit) fishing mortality rate in the next year will be similar to the value estimated for 1997. Last year we showed that since the SPR rates are a function of gear selectivity, and the selectivity between trawl and longline gear is quite different, not knowing the relative harvests between gears can be misleading for deriving an SPR rate. For example, longline gear tends to harvest the older segment of the stock, consequently, they are able to harvest at a higher rate and still maintain reasonable spawning stock reserves. Also, please note that we assume that spawning occurs during the month of April (Ianelli *et al.* 1994).

We attempt to present an alternative way to summarize the uncertainty in our yield recommendations. Typically, we estimate the SPR fishing mortality rate (e.g., $F_{40\%}$) by using the fixed assumed (or estimated) values of natural mortality, growth, and fishery selectivity. We then apply this rate to a single (or series of) point estimate(s) of projected stock size to compute the ABC value. This year we devised a method of doing these computations within the estimation framework, thereby enabling us to carry through measures of uncertainty in yield estimates. Without going into great detail, this technique involves using the Delta method, also referred to as propogation-of-error. This simply is a way of showing the uncertainty of functions that involve random variables. For example, how does current stock size vary if natural mortality is treated as a random variable? Also, how do these uncertain quantities affect estimates of yield under the $F_{40\%}$ harvest rate? The result from this application is shown in Figure 9.16. This figure requires some interpretation. The vertical axis represents the cumulative odds that the "true" yield at a given SPR rate is less than the value on the horizontal axis. For example, following the $F_{40\%}$ curve along until the horizontal axis reads 1,774 tons gives a vertical scale of 25%. This implies that there is (approximately) a 25% chance that the "true" yield at the $F_{40\%}$ harvest rate is *less* than 1,774 tons. Interestingly, the "point" estimate of 1,990 tons under the $F_{40\%}$ level coincides with a very minute probability that the overfishing level ($F_{30\%}$) would be exceeded. This framework can also be used to reflect the uncertainty in future catch by different gear types.

Table 9.7. Reference fishing mortality rates (coefficient of variation in parenthesis), and yield for 1999 with upper and lower 25 percentiles for ABC and OFL computations. Fishing mortality rates expressed as full selection values.

	Longline	Trawl	
$F_{40\%}$	0.038	0.040	
	(18%)	(15%)	
$F_{30\%}$	0.058	0.055	
	(17%)	(19%)	

	25%	**50%**	**75%**
ABC	1,774	**1,990**	2,233
$F_{35\%}$	2,101	2,365	2,663
OFL	2,499	2,829	3,202

*Assuming relative catch in 1999 is the same between the gear types.

Table 9.8. Model estimates of the trend in average (ages 5-54) and full selection fishing mortality rates by gear type and combined for shortspine thornyheads in the Gulf of Alaska.

		Average F			**Full selection F**	
Year	**Trawl**	**Longline**	**Combined**	**Trawl**	**Longline**	**Combined**
1978	0.006	0.006	0.012	0.015	0.010	0.024
1979	0.009	0.008	0.017	0.021	0.013	0.034
1980	0.017	0.006	0.022	0.038	0.009	0.047
1981	0.016	0.003	0.020	0.037	0.006	0.043
1982	0.010	0.002	0.012	0.022	0.003	0.025
1983	0.009	0.002	0.011	0.020	0.003	0.023
1984	0.003	0.001	0.003	0.006	0.001	0.007
1985	0.001	0.000	0.001	0.002	0.000	0.003
1986	0.009	0.002	0.010	0.020	0.003	0.022
1987	0.027	0.000	0.027	0.061	0.000	0.061
1988	0.032	0.001	0.033	0.073	0.001	0.074
1989	0.040	0.001	0.041	0.091	0.002	0.093
1990	0.021	0.005	0.026	0.048	0.009	0.057
1991	0.022	0.013	0.035	0.050	0.021	0.072
1992	0.021	0.016	0.037	0.047	0.026	0.073
1993	0.012	0.014	0.026	0.028	0.022	0.050
1994	0.013	0.012	0.025	0.029	0.020	0.049
1995	0.014	0.012	0.027	0.033	0.020	0.053
1996	0.013	0.013	0.026	0.030	0.021	0.051
1997	0.014	0.010	0.024	0.033	0.016	0.049
1998	0.019	0.021	0.040	0.044	0.033	0.078

Acceptable biological catch

The 1999 $F_{40\%}$ harvest level for shortspine thornyheads in the GOA is **1,990 t**. This is nearly identical to last year's $F_{40\%}$ rate of 2,000 t. The long-term expected value of spawning biomass with fishing held at $F_{40\%}$, referred to as the $B_{40\%}$ level, is estimated at about 16,300 t. This is substantially lower than the current estimate of female spawning biomass of 23,100 t. Therefore, under the ABC and overfishing definitions (Plan Amendment 44), no adjustment to the $F_{40\%}$ harvest rate is required.

Overfishing level

The Council's overfishing definition is the fishing mortality rate which reduces the spawning biomass per recruit to 30% of its pristine level. For shortspine thornyheads in the Gulf of Alaska that value (average over all ages) corresponds to F=0.112 (full selection). This rate corresponds to a catch level of **2,800 t** in 1999, assuming that the catches by gear type catch are equal.

Other considerations

Currently thornyheads are managed for the entire Gulf of Alaska. Based on the most recent three survey estimates weighted as for other rockfish (4, 6, and 9 respectively for 1990, 1993, and 1996) gives the following apportionment of shortspine thornyheads ABC broken out by management areas:

Biomass (tons)					
	Year	Western	Central	Eastern	Total
	1990	1,679	5,941	11,997	19,617
	1993	3,706	12,509	16,808	33,023
	1997	8,043	18,741	24,912	51,696
Proportion		Western	Central	Eastern	Weight
	1990	9%	30%	61%	4
	1993	11%	38%	51%	6
	1997	16%	36%	48%	9
		Western	Central	Eastern	Total
wtd. Average		13%	36%	52%	
	ABC	**259**	**716**	**1,035**	**1,990**

Historical removals by foreign vessels appears to have been more concentrated in the central region (Ianelli and Ito, 1995). Since this pattern may reflect current trends, we recommend that management of thornyheads be broken into these regions rather than Gulf-wide. Presently it is impossible to determine the relative magnitude of thornyhead removals in these areas since observer coverage is not evenly distributed. Further considerations on future harvest levels must also account for the impact of trawl closure areas in the eastern portion of the GOA. The impact of this closure will likely shift the relative proportion caught by gear type, but since this will increase the proportion caught by longline gear, the harvest levels recommended here are likely to be more conservative than if the pressumed shift in catch by gear type was accepted.

Summary

The management parameters of interest derived from this assessment are presented in Table 9.9. Please note, however, that management actions should be based on a more complete evaluation of the alternatives presented above rather than the single values given here.

Table 9.9. Summary management values based on this 1998 assessment for shortspine thornyheads in the Gulf of Alaska.

Management Parameter	Value
M (natural mortality)	0.0790 yr^{-1}
Approximate age at full recruitment	Younger for trawl, older for longline
$F_{30\%}$ (Full selection)	0.112
$F_{40\%}$ (Full selection)	0.078
Unfished female spawning biomass	40,680 t
Long-term $B_{40\%}$ (female spawning biomass)	16,300 t
1999 female spawning biomass	23,100 t
1999 age 5+ biomass	52,100 t
F_{abc}	0.078
ABC (Reference model)	**1,990 t**
$F_{overfishing}$	0.112
Overfishing level	**2,800 t**

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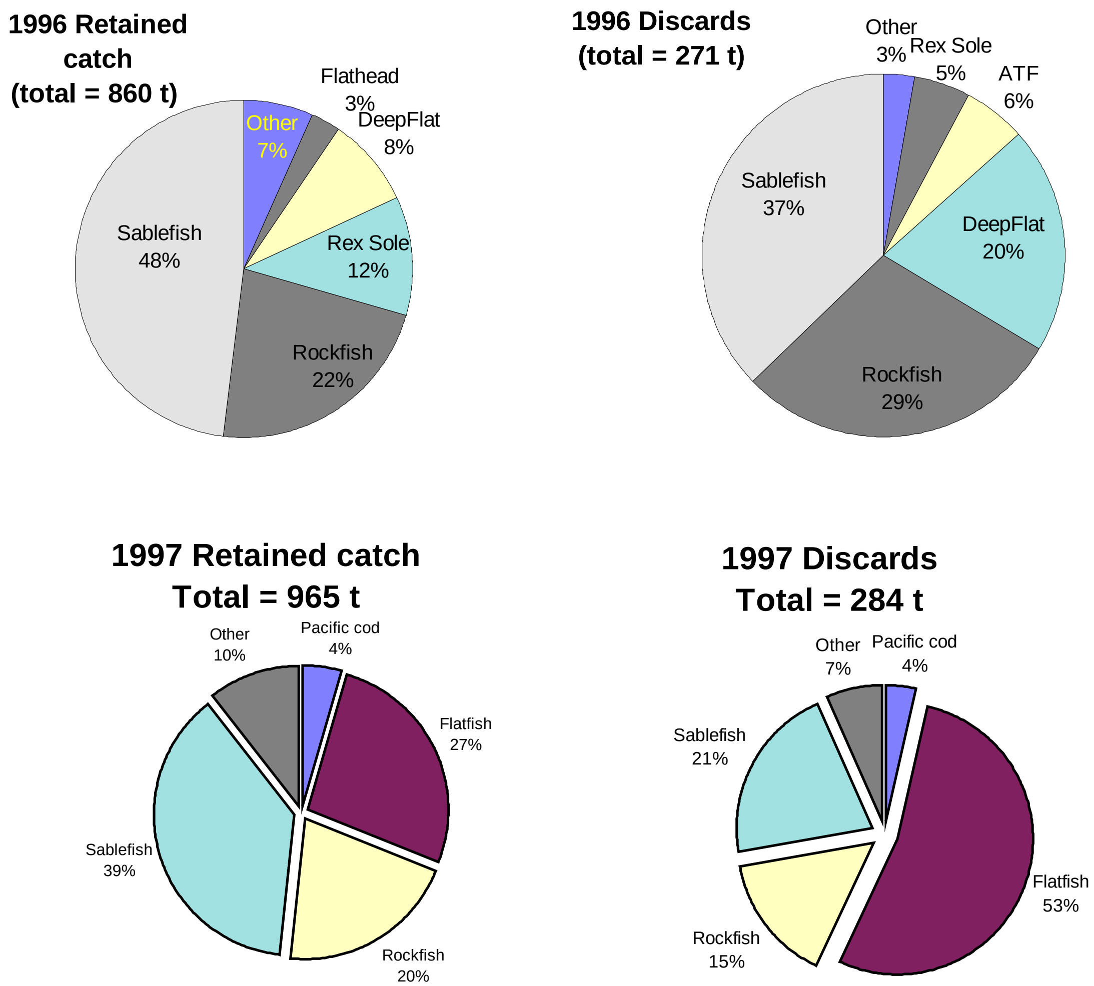


Figure 9.1. Proportion retained and discarded shortspine thornyhead by target fishery in 1996 and 1997. *Source: NMFS Alaska Fisheries Science Center and Regional Office blend data.*

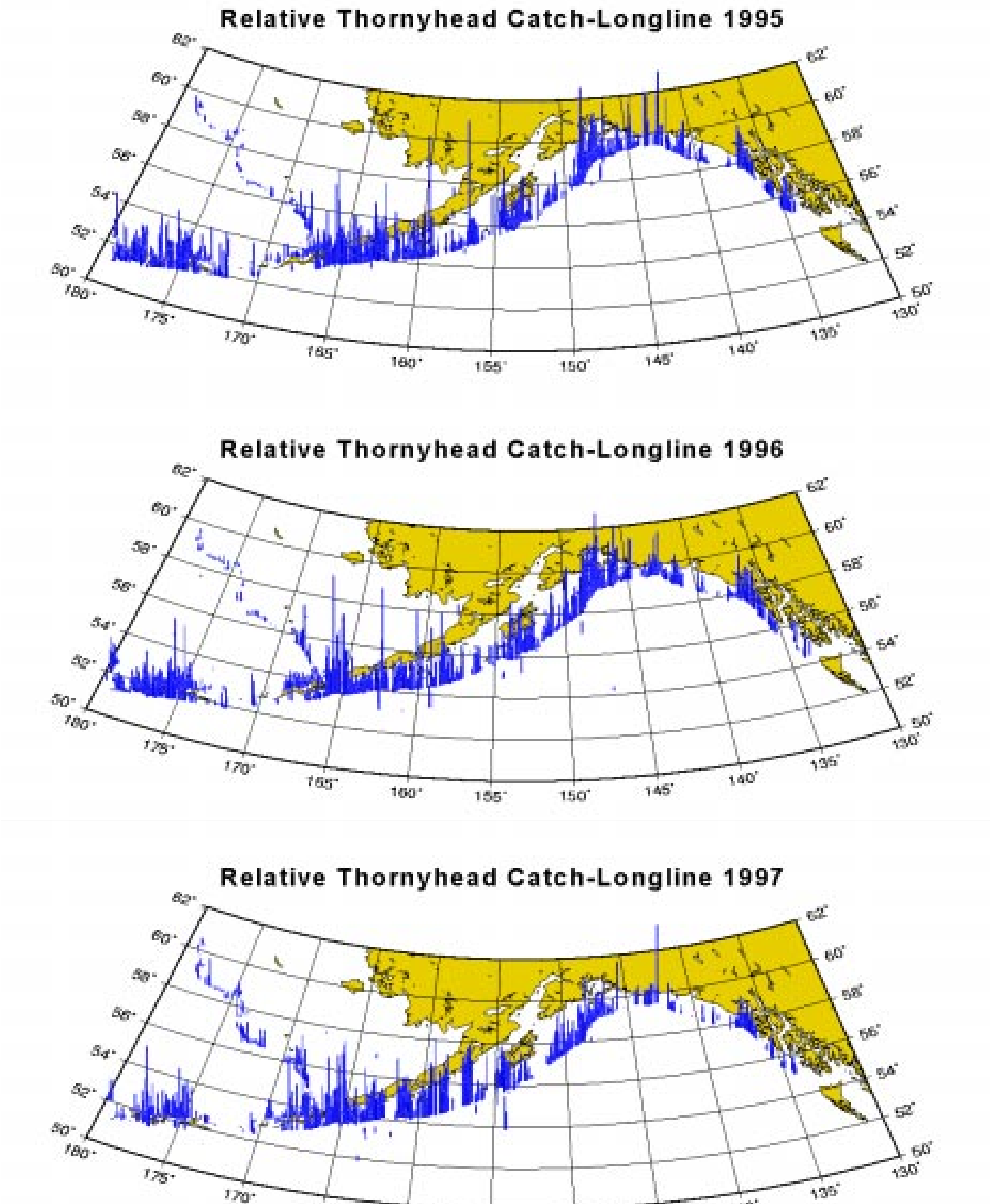


Figure 9.2. Distribution of thornyhead catches by commercial longline gear, 1995-1997.

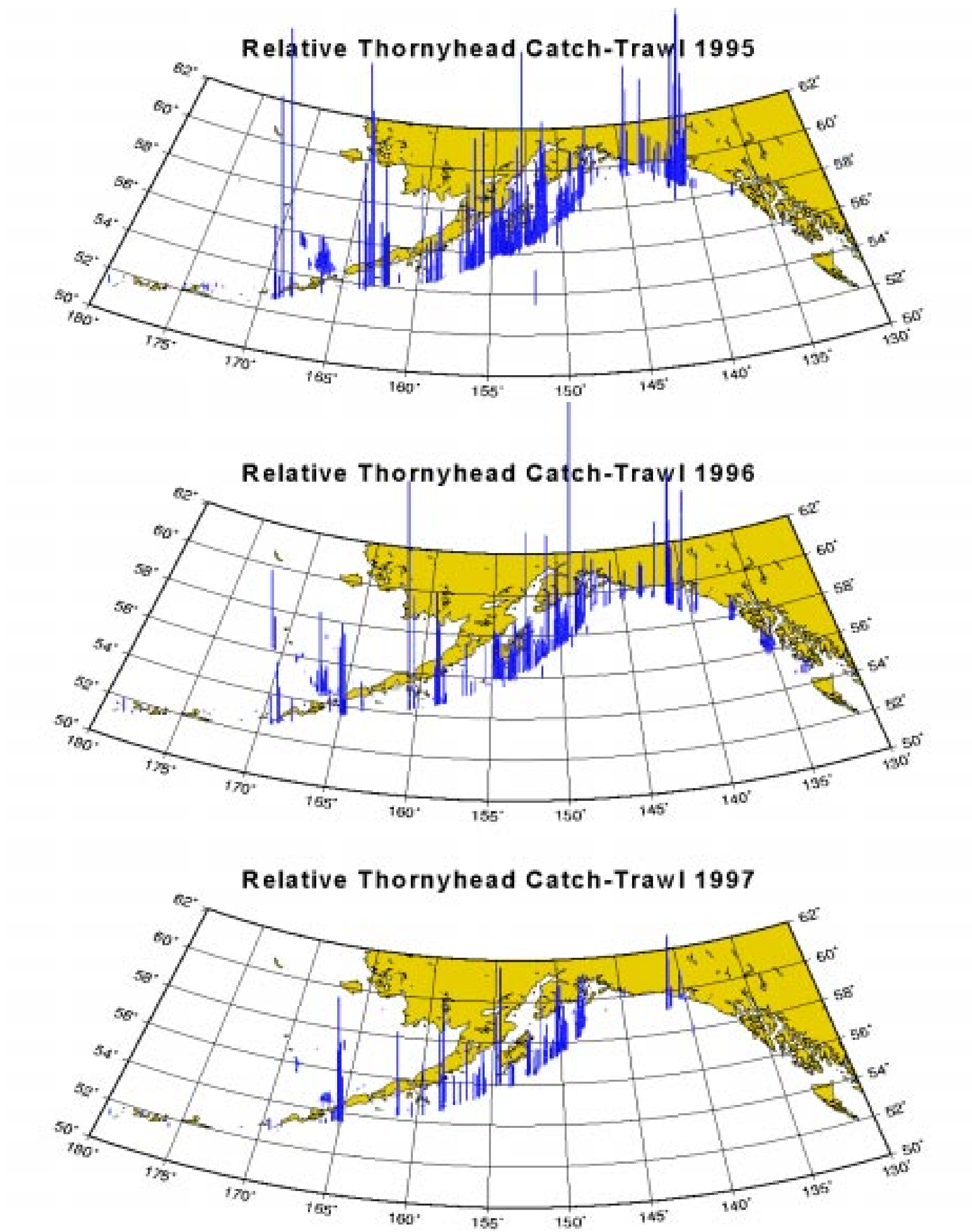


Figure 9.3. Distribution of thornyhead catches by commercial trawl gear, 1995-1997.

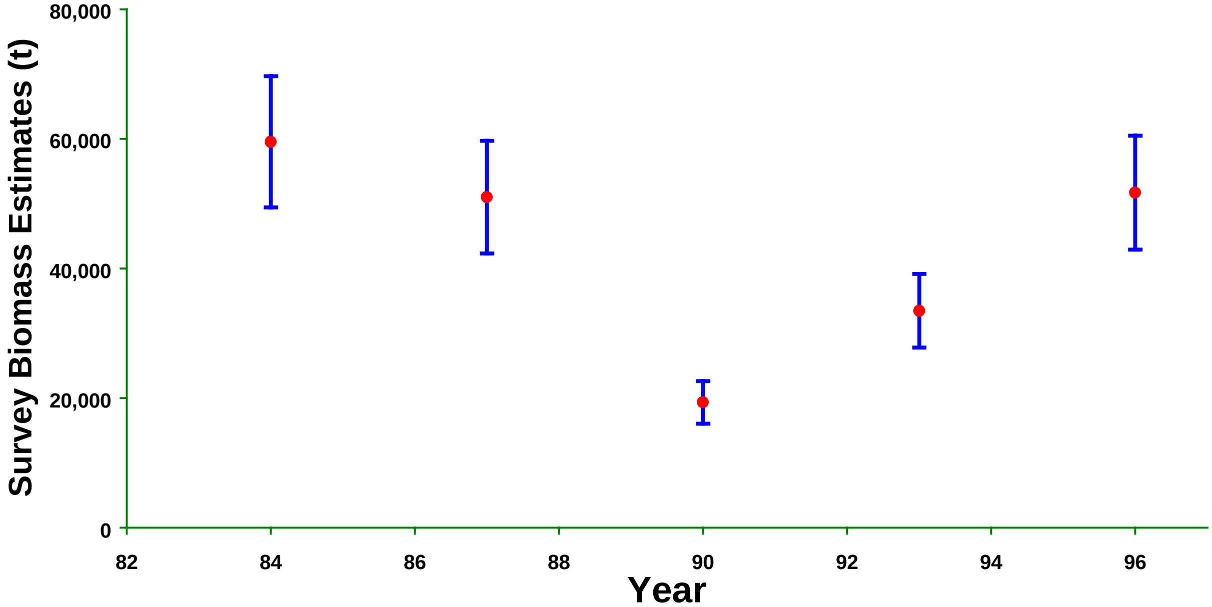


Figure 9.4. Shortspine thornyhead biomass estimates (and standard errors) from the NMFS triennial trawl survey. Note that the 1990, 1993, and 1996 surveys did not extend to deep water (>500m), consequently, a considerable proportion of the stock was not sampled.

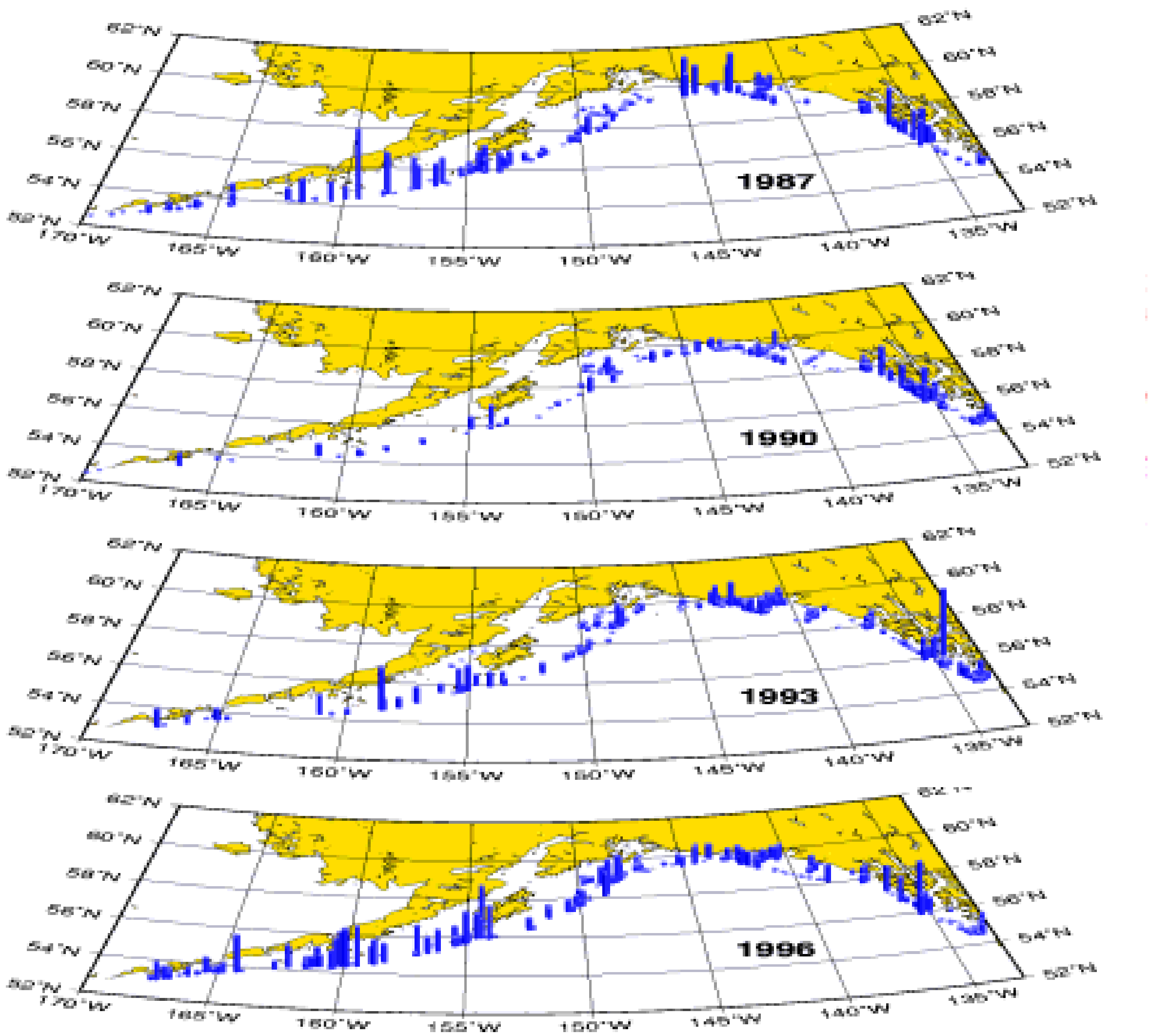


Figure 9.5. Distribution of thornyhead CPUE from recent triennial trawl surveys. Height of vertical bars is proportional to CPUE by weight.

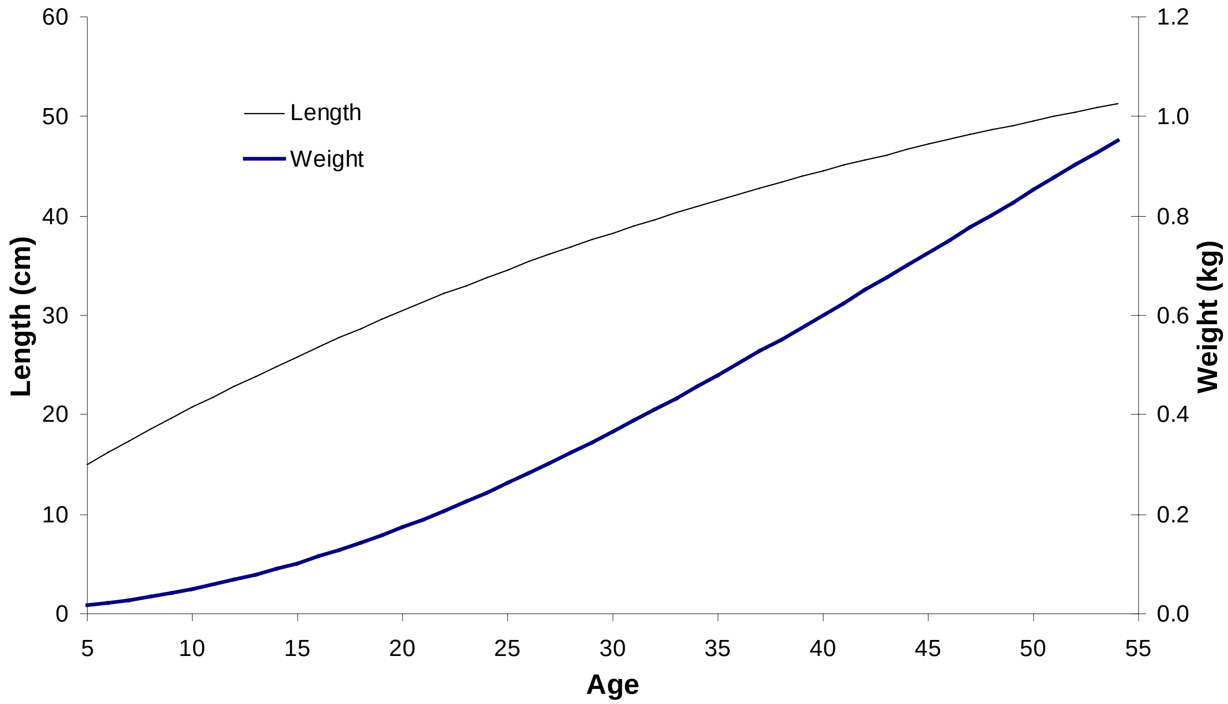


Figure 9.6. Assumed average length and weight at age for Gulf of Alaska shortspine thornyheads.

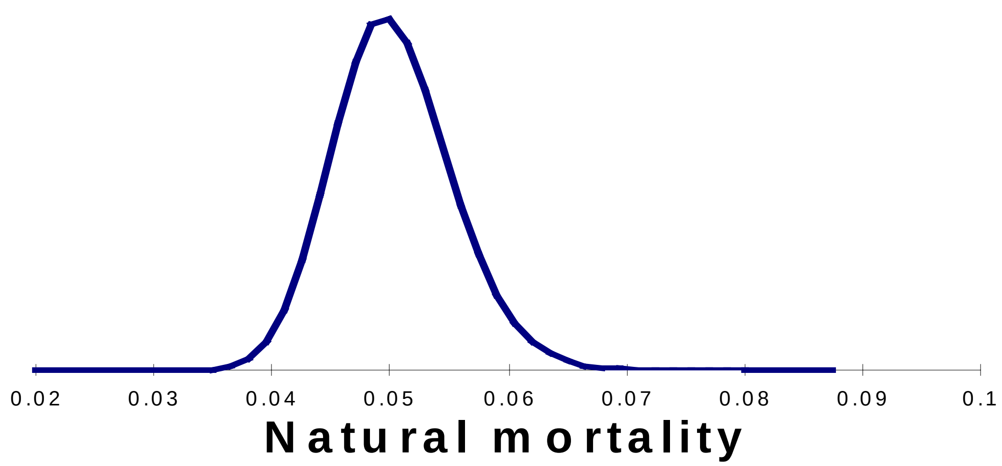


Figure 9.7. Prior distribution assumed for natural mortality of thornyheads.

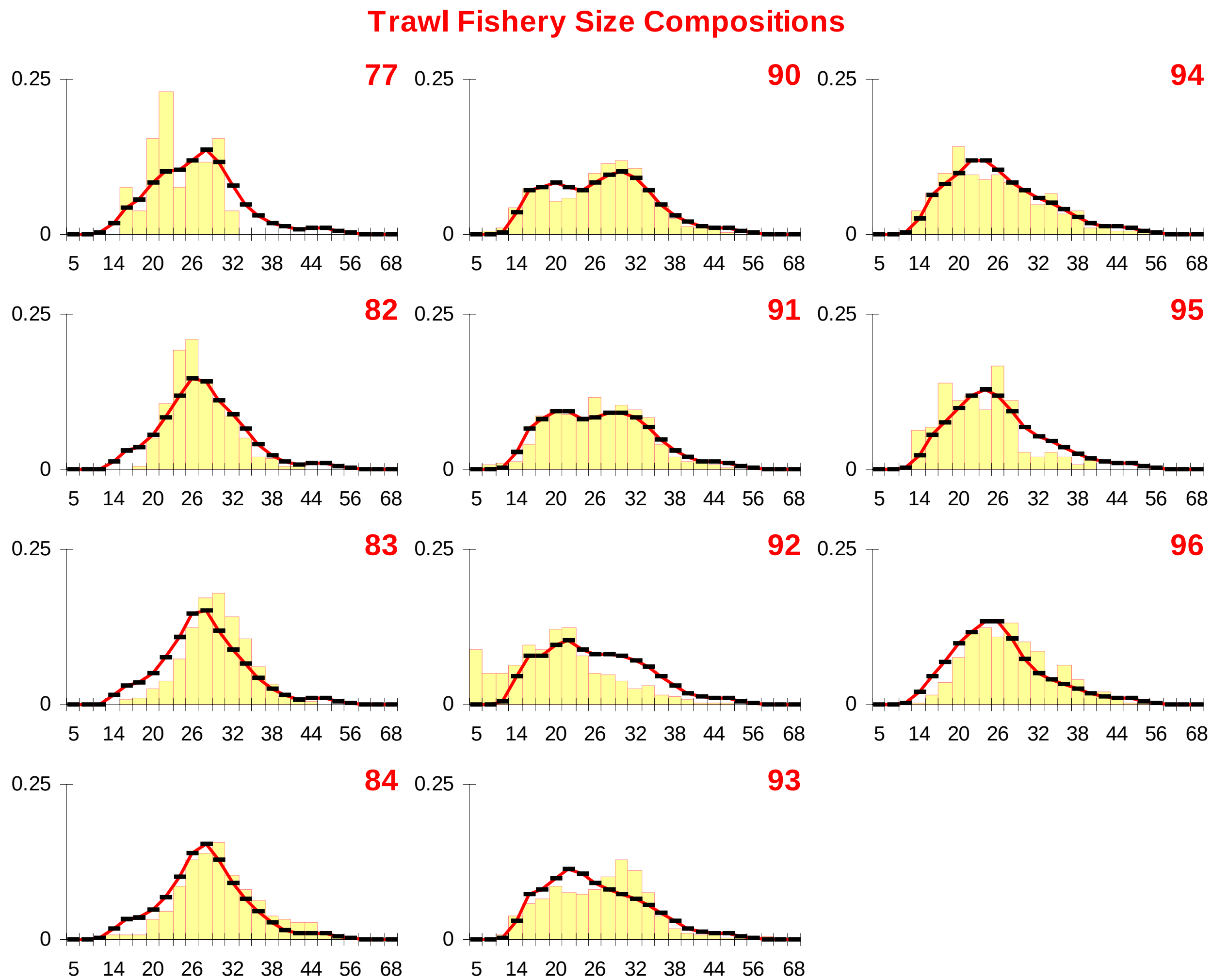


Figure 9.8. Model fits to the trawl shortspine thornyheads fishery size composition data.

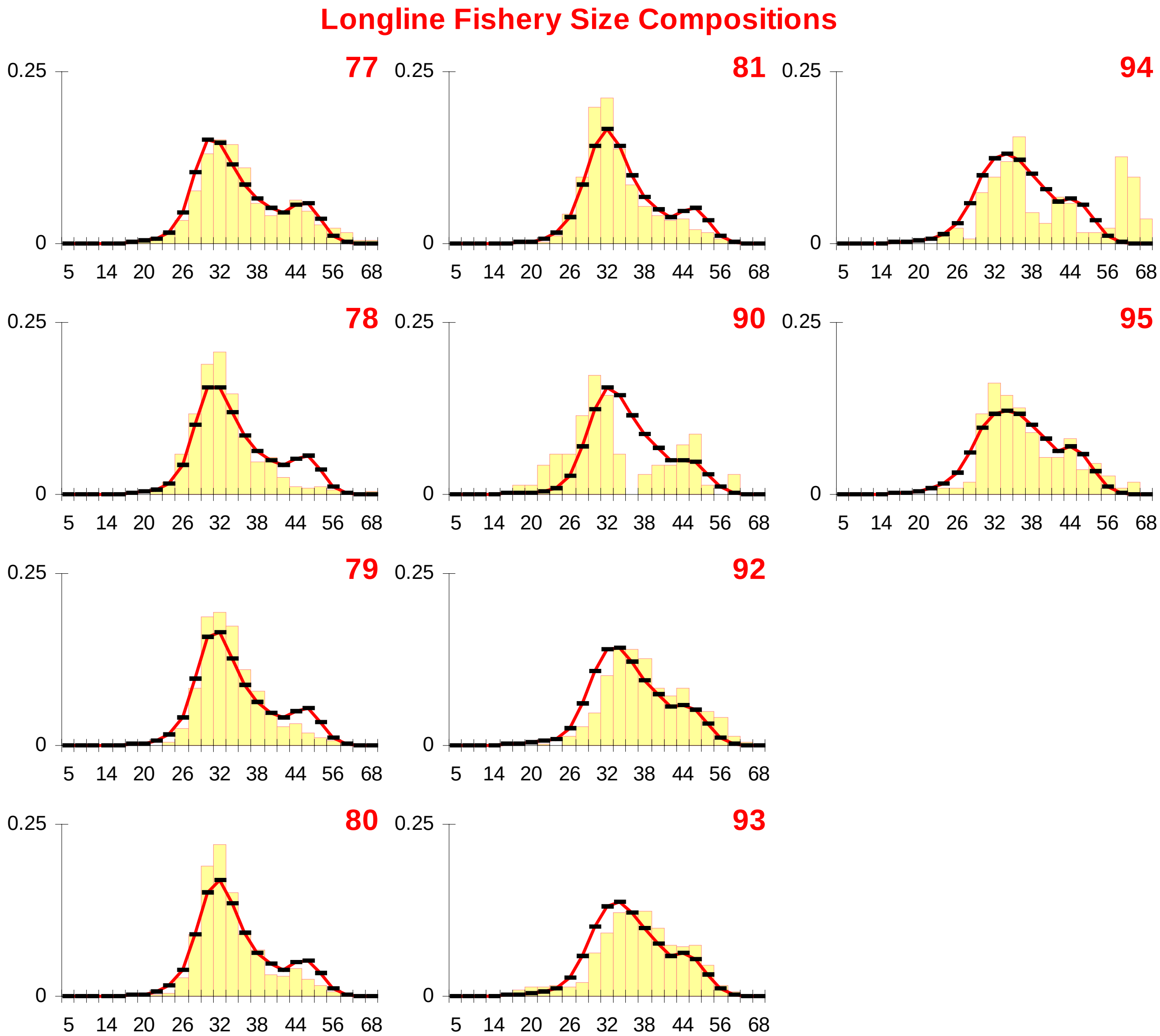


Figure 9.8. (Cont'd) Model fits to the longline shortspine thornyheads fishery size composition data.

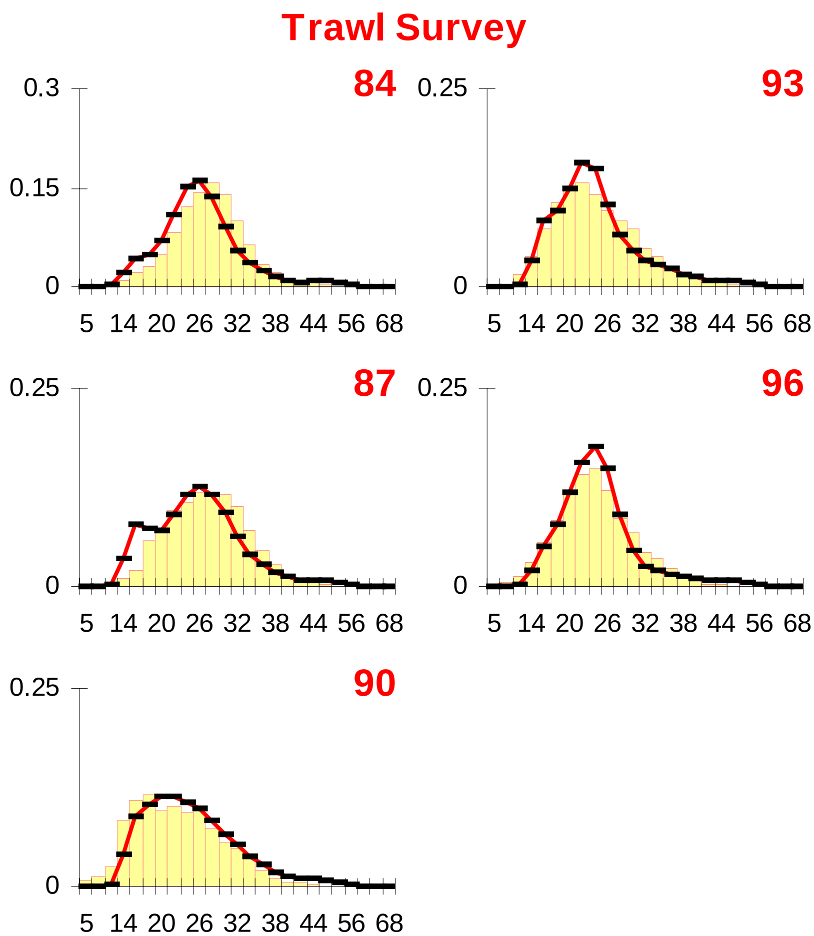


Figure 9.8. (Cont'd) Model fits to the trawl survey size composition data.

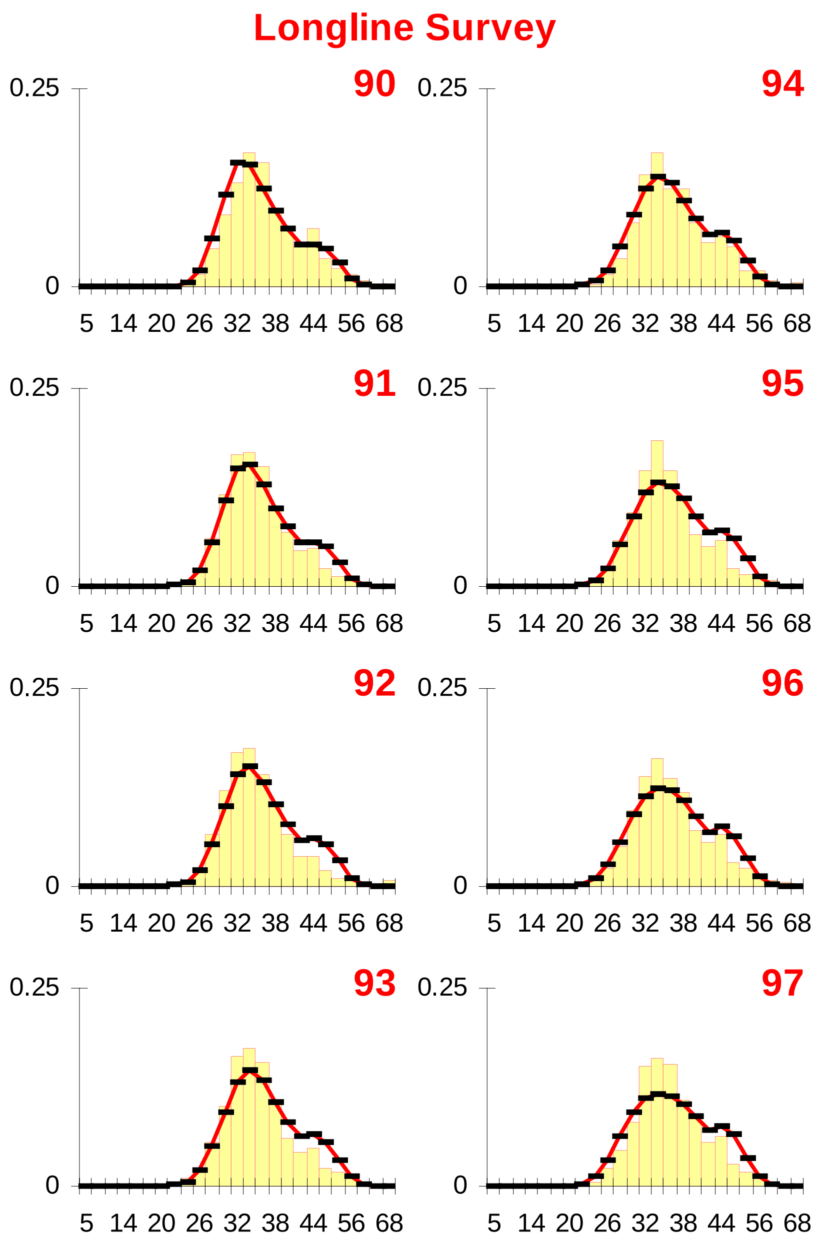


Figure 9.8. (Cont'd) Model fits to the longline survey shortspine thornyheads size composition data.

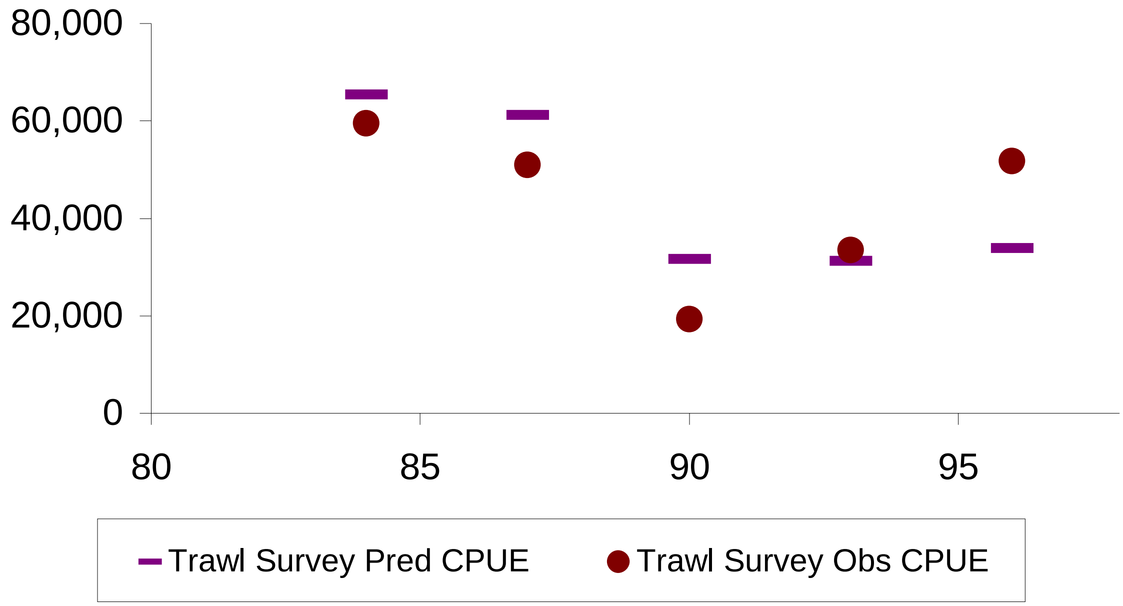


Figure 9.9. Model fits to the relative abundance index from the longline surveys (RPN, top panel) and the triennial trawl surveys (bottom panel) for shortspine thornyheads. Note that the triennial survey was modeled with two catchability terms to reflect the change in distribution covered by the survey after 1989.

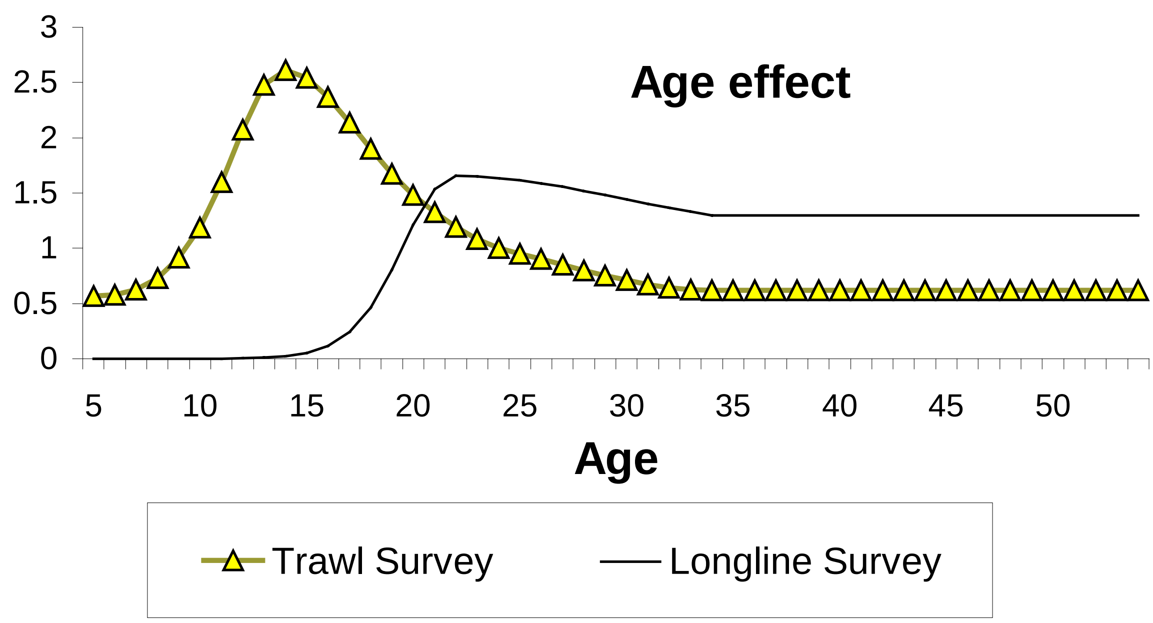


Figure 9.10. Selectivity of shortspine thornyheads estimated for the surveys (sized-based, upper panel) and fisheries (age-equivalent estimates, lower panel).

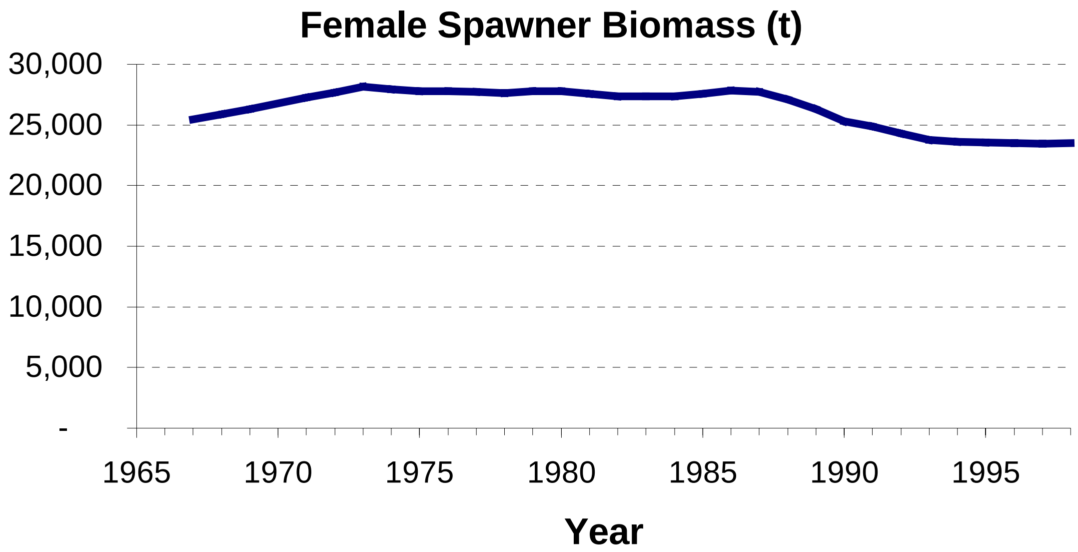


Figure 9.11. Estimated female spawner biomass trajectory for shortspine thornyheads in the Gulf of Alaska.

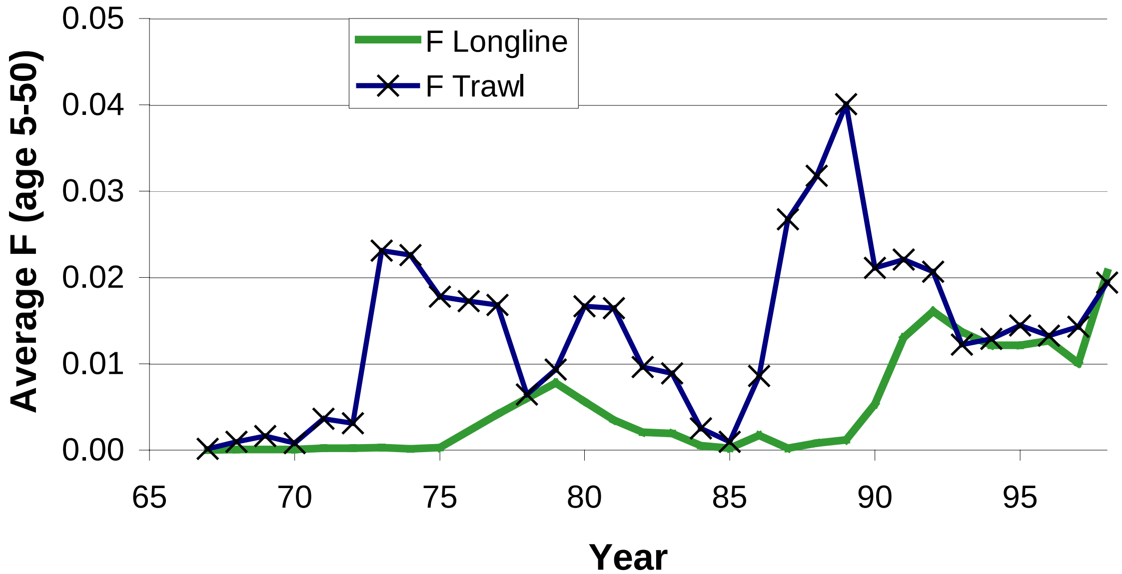
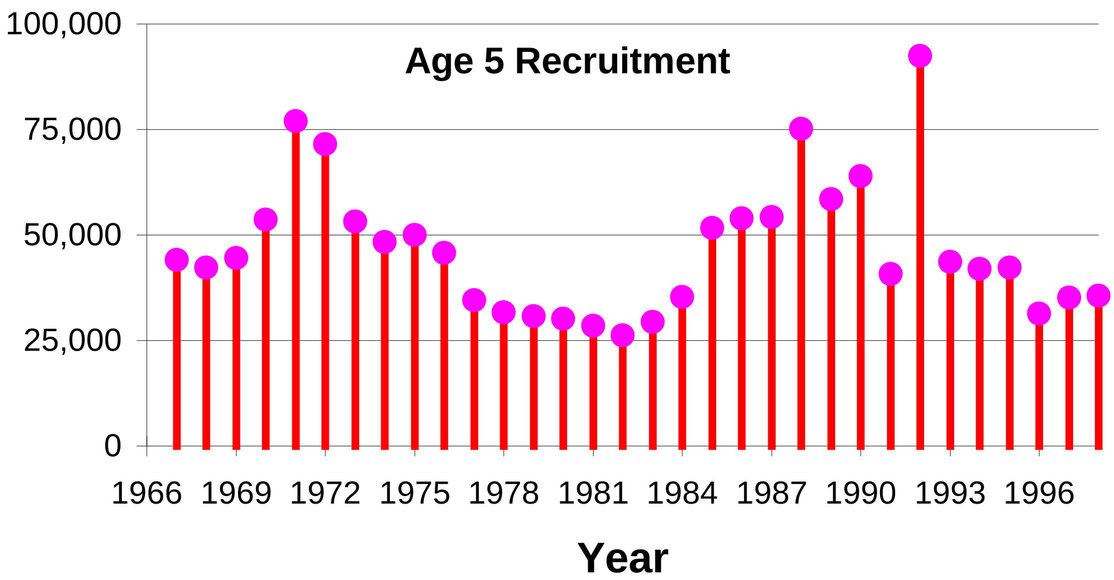


Figure 9.12. Average (over ages 5-54) fishing mortality rate by gear type on shortspine thornyheads in the Gulf of Alaska, 1967-1997.



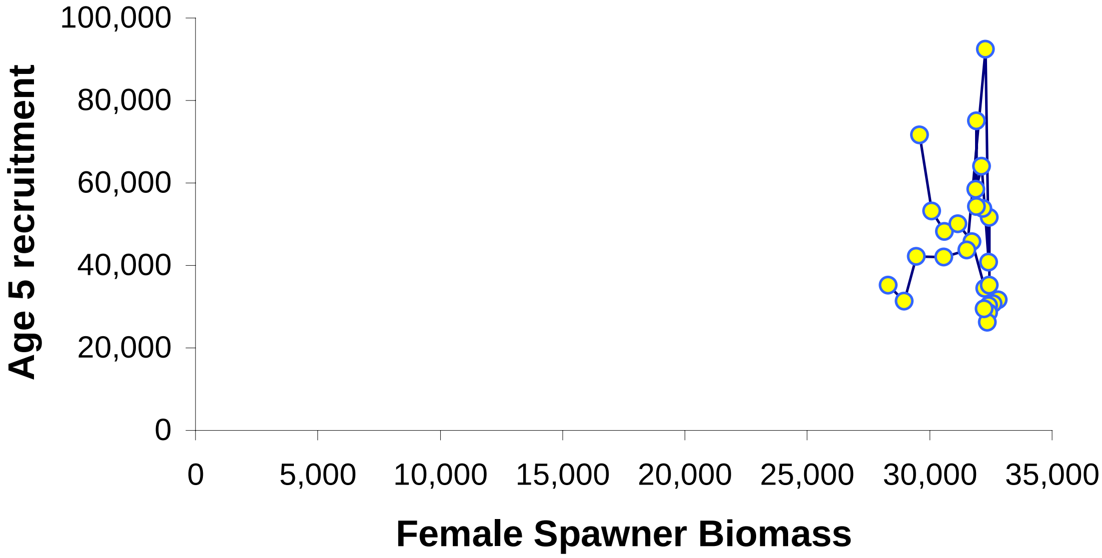


Figure 9.13. Time series of recruitment strengths (upper panel) and the stock-recruitment plot (lower panel) for shortspine thornyheads in the Gulf of Alaska.

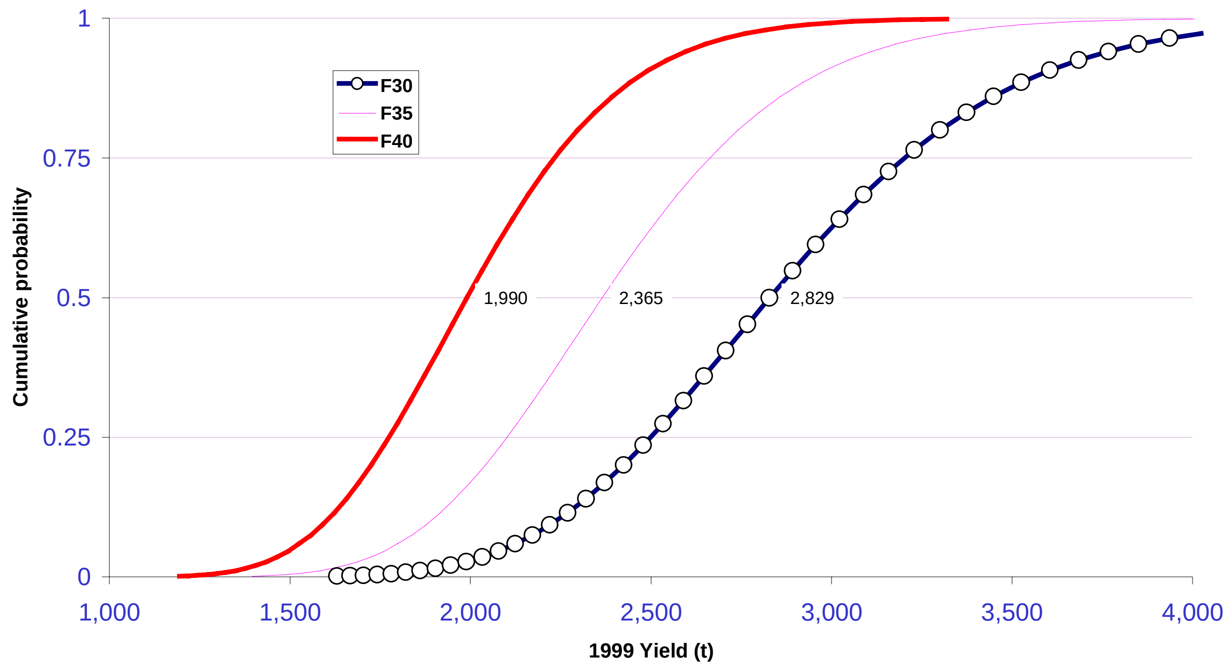


Figure 9.14. Projected 1999 shortspine thornyhead yield three under alternative SPR harvest rates. The cumulative probability reflects uncertainty in the current stock size in addition to uncertainty in estimating the SPR rates themselves.

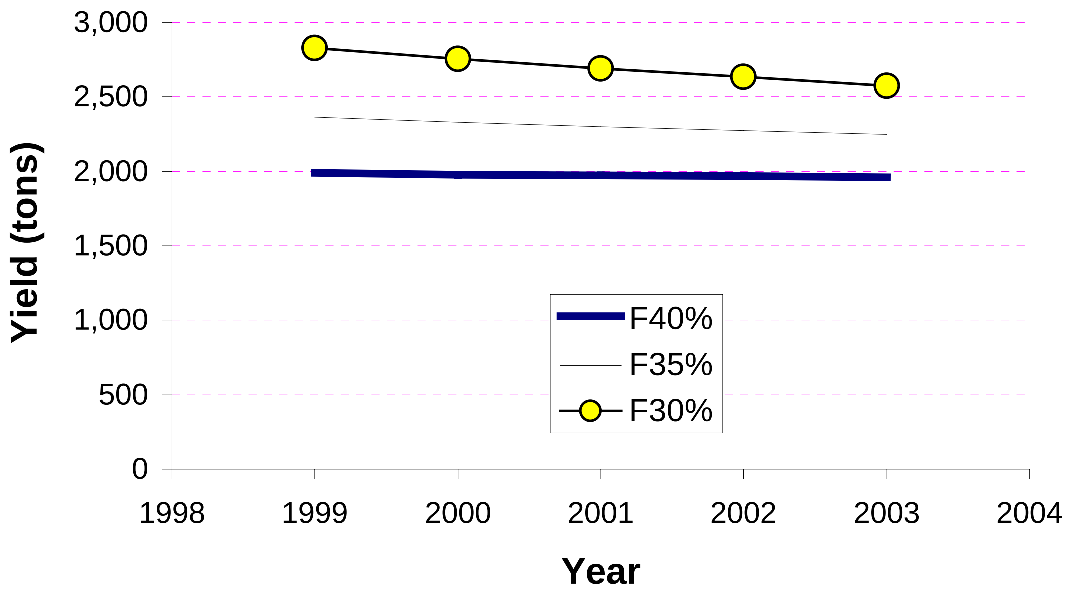


Figure 9.15. Projected future yield of shortspine thornyheads under alternative SPR fishing mortality rates.

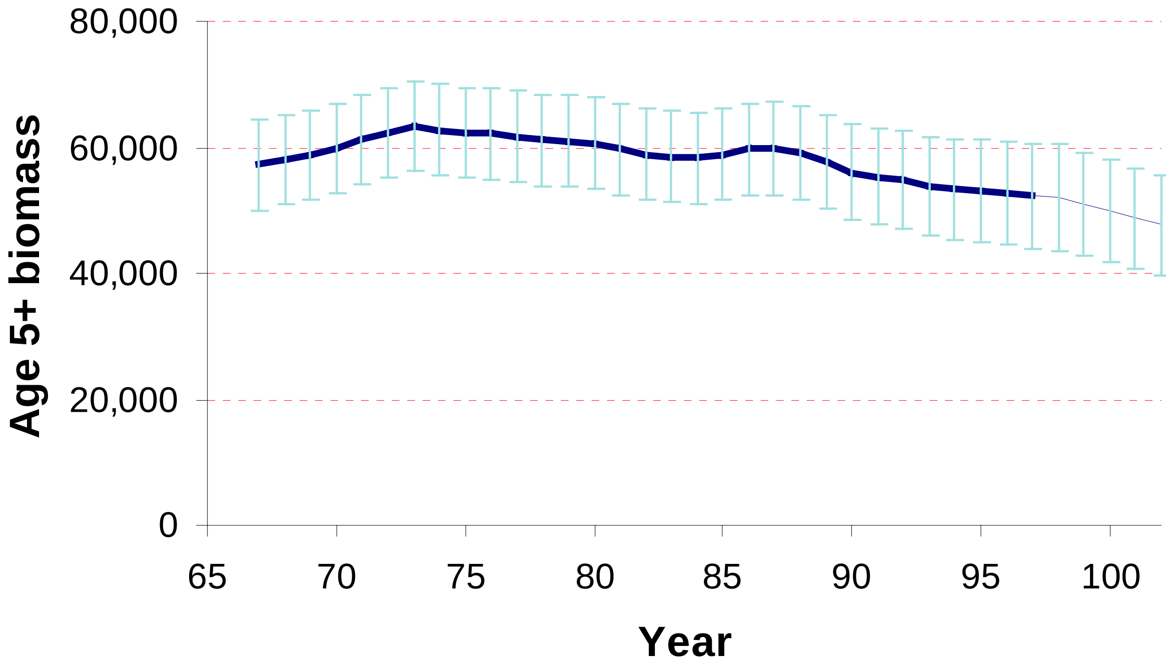


Figure 9.16. Historical and projected shortspine thornyhead age 5+ biomass with 2 standard deviations. Note that future projections are based on an assumed $F_{40\%}$ fishing mortality rate.